Small Group Experiments in Collaborative Virtual Environments

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Abstract

Presence in Collaborative Virtual Environments (CVEs) can be classified into *personal presence* and *co-presence*. Personal presence is having a feeling of "being there" in the CVE yourself. Co-presence is having a feeling that one is in the same place as the other participants, and that one is collaborating with real people. In this paper we present two experiments designed to investigate some of the factors affecting personal presence and co-presence in Collaborative Virtual Environments (CVEs). The first experiment investigates the effects of group collaboration and interaction on presence and co-presence in a CVE. The second experiment investigates the effects of avatar appearance and functionality (in terms of simple gestures and facial expressions) on co-presence in the CVE.

Keywords: ***Presence, Collaborative Virtual Environments, Virtual Reality***

1 Presence In Collaborative Virtual Environments

Collaborative Virtual Environments (CVEs) make use of a distributed architecture and advanced interactive user interfaces to create a 'shared' space where multiple users, located in different geographical locations can interact and collaborate. Several authors [2, 3, 12] have claimed that CVEs may support collaboration and interactivity in ways which go beyond what is possible using more familiar meeting room or teleconferencing technologies.

However, in order for such systems to be usable and successful, they need to provide the participants with a compelling experience and a high sense of *presence*, to convince them that they are present in the virtual environment, and that they are collaborating with real people.

Presence (or personal presence) refers to the psychological sensation of "being there", having a sense of being in the place specified by the virtual environment rather than just seeing images depicting that place. According to Steuer [9] presence means "The feeling of 'being in an environment'." *Co-presence* is the feeling that the other participants in the VE actually exist and are really present in the environment, and the feeling that one in interacting with real people.

In this paper we present two experiments which are designed to investigate some of the factors believed to affect personal presence and co-presence in a collaborative virtual environment. Section 2 describes an experiment which investigates the effects that small group collaboration has on personal presence and co-presence in a collaborative virtual environments. Section 3 presents an experiment designed to investigate the effects that avatar appearance and functionality have on co-presence in the CVE.

2 Experiment 1: The Effects of Group Collaboration on Presence

In this section, we present an experiment which investigates the effects that small group collaboration has on personal presence and specially co-presence in a Collaborative Virtual Environment. A high sense of co-presence in a CVE is crucial to enable a group of people to collaborate and interact effectively. However, it is equally important to investigate if collaboration and interaction between a group of people effect co-presence in a CVE.

2.1 Presence and Collaboration: Hypotheses

This experiment was designed to test the following hypotheses:

1. Group collaboration and interaction with other participants in the environment should influence co-presence. It is believed that simply having a virtual representation of other users in the environment is not sufficient to create a high sense of co-presence. Having the possibility to collaborate and interact with other participants in the

shared environment should very much increase the sense of co-presence.

2. Personal presence and co-presence in a CVE could be correlated. Slater *et al* [6] postulate that personal presence is a prerequisite for co-presence. It would be useful to know whether these two types of presence are associated, since if personal presence and co-presence are associated this could be because of common factors which influence both, or because they influence one another. Tromp *et al* [11] and Slater *et al* [8] found in one of their small group experiments that the presence and co-presence scores were positively correlated.

2.2 Collaborative Virtual Environment Prototype

In this experiment, we developed two collaborative virtual environments, which we named 'high-collaboration VE' and 'low-collaboration VE'. Both VEs are basically identical and only the task differs. In the high-collaboration VE, participants have to collaborate to solve the given task. In the low-collaboration VE, participants don't need to collaborate to solve the problem.

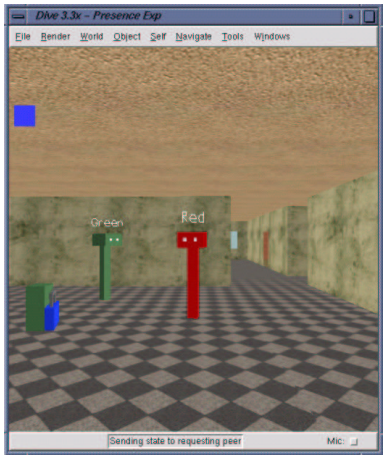

Figure 1: The high-collaboration VE, consisting of a set of rooms forming a maze. In this picture, the Blue participant is looking at the Red and Green participants.

The VEs consisted of a set of rooms which creates a simple maze (see Figure 1). Participants are able to move their avatar around the rooms using the arrow keys, and move their avatar's head using the mouse. They are able to pick up objects in the VE by clicking on them, which attaches the object to their avatar. They are therefore able to move the object by moving themselves, and then release the object by clicking on it again. Participants can communicate with each other using an audio channel.

In this experiment, all the participants have an identical avatar, consisting of a 'T' shaped block avatar called 'Blockie'. The only difference between the participant's avatars is their colour being red, green or blue (see Figures 1 and 2). The avatars where labeled Red, Green and Blue, and participants called each other by these names during the experiment.

Figure 2: The Red participant has picked up the red pyramid, and can now move around and drop the shape in the appropriate room.

In the high-collaboration VE, each participant has an avatar of a given colour (red, green or blue), and the shapes are also red, green or blue in colour. All the shapes are locked by padlocks (refer to Figures 1 and 2) and participants cannot pick up locked shapes. The padlocks are also coloured red, green or blue. In addition, only the participant with the same colour as the shape can pick up that shape, and only the participant with the same colour as the padlock can unlock that padlock. Therefore, picking up a red shape locked with a blue padlock involves having the Red and Blue participants within a close range of the shape, and having the Blue participant unlock the blue padlock by clicking on it. Clicking on the padlock causes it to open for 6 seconds, after which it automatically locks itself. During those 6 seconds, the Red participant can pick up the shape by clicking on it. The shape gets attached to the Red avatar, and he/she can move around the virtual environment and drop the shape in the appropriate room. We chose this task because it requires observation and talking, and can only be solved by collaboration since two participants are needed to pick up a shape.

In the low-collaboration VE, the task is basically the same except that there are no padlocks locking the shapes. Therefore, a given shape can be picked up by the user having the same colour as the shape, without needing the help of another participant. This means that participants don't need to collaborate to move the shapes around, and so this task can be completed without any collaboration.

2.3 Experimental Procedure

This experiment involved 30 participants, divided into 10 groups of 3 users each. The first 4 groups (12 participants) were assigned to the low-collaboration VE, and the next 6 groups (18 participants) to the high collaboration VE. None of the participants knew that there were two different VEs. Participants were second year psychology students.

Before starting the experiment, each participant was introduced to the system. This involved learning how to move in the environment and how to pick up objects and drop them somewhere else. Once every participant was familiar with the interface, they read the experiment instructions describing the task that they had to perform in the virtual environment.

The task had a time limit of 25 minutes, but this was not mentioned to the participants as knowledge of the time limit might affect task performance. Once the time elapsed, the participants where instructed to stop, and then to fill in some questionnaires: the Immersive Tendencies Questionnaire, the personal presence and co-presence questionnaire, and the collaboration questionnaire. The questionnaires are used to measured the following variables: personal presence (P), co-presence (CO-P), immersive tendencies (IT), and collaboration (COLL).

The personal presence questionnaire is based on the questionnaires developed by Slater *et al* [7, 5]. To measure co-presence, we have developed a co-presence questionnaire which uses questions similar to the ones proposed by Slater *el al* in [6].

The Immersive Tendencies Questionnaire (ITQ) developed by Witmer and Singer [13] is used to measure differences in the tendencies of individuals to become immersed. The items in this questionnaire mainly measure involvement in common activities. Since increased involvement can result in more immersion, we expect individuals who tend to become more involved will also have greater immersive tendencies.

We measure subjectively rated collaboration by making use of a post-experiment questionnaire. This collaboration questionnaire is used to make sure that the two VEs (i.e., the low-collaboration VE and the high-collaboration VE) produced different levels of collaboration and interaction.

2.4 Results

In order to check that both VEs produced a different level of collaboration, we performed a one-way ANOVA to check the difference in COLL score between the low-collaboration VE and the high-collaboration VE. We found that, as expected, there was a very large difference in collaboration score between both VEs, with $F(1, 28) = 145.025, p < 0.001$. This shows that participants felt that they collaborated quite a lot in the high-collaboration VE, and not at all in the low-collaboration VE.

We then compared the difference in the P scores between the low and high-collaboration VEs. This was done using a one-way ANOVA, and we found that there was a significant difference at the 0.05 confidence level, with $F(1, 28) = 16.366, p < 0.05$. This indicates that participants had a higher P score on the high-collaboration VE.

We also compared the CO-P scores between the low and high-collaboration VEs. This was achieved by doing a one-way ANOVA on co-presence scores for both VEs. We found that there was a very significant difference, having $F(1, 28) = 63.317, p < 0.001$. This difference indicates that participants in the high-collaboration VE had a greater sense of co-presence than participants in the low-collaboration VE.

A correlation analysis was performed on the P, CO-P, IT, and COLL scores in each VE, to check if there were significant relationships between them. In the low-collaboration VE, we found a significant correlation between the P and the IT scores ($p = 0.02$). We did not find any significant correlation between CO-P and IT scores, or between P and CO-P. We found a significant correlation ($p = 0.01$) between CO-P and COLL, but not between P and COLL, or IT and COLL. In the high-collaboration VE, we also found a significant correlation between the P and the IT scores ($p = 0.01$). Also, we did not find any significant correlation between CO-P and IT scores, or between P and CO-P. We found a significant correlation ($p = 0.04$) between CO-P and COLL, but not between P and COLL, or IT and COLL.

2.5 Discussion of Results

We found that there was a very large difference in co-presence between the two conditions. The co-presence score was much higher in the high-collaboration VE then in the low-collaboration VE. This supports our hypothesis that just having virtual representations of others is not sufficient to create a high sense of co-presence, and that one needs collaboration and interaction in order to enhance co-presence in a CVE.

When looking at the presence scores, we found that the presence score was higher in the high-collaboration VE than in the low-collaboration VE. This indicates that collaboration and interaction with other participants affects personal presence. This might be explained by the fact that since the high-collaboration task was more challenging, it required the participant to be more involved in the experience and hence enhances the sense of personal presence.

Witmer and Singer [13] indicate that their Immersive Tendencies Questionnaire predicts the level of presence recorded with their presence questionnaire in a VE. Since we have used a different presence questionnaire based on the questionnaire developed by Slater *et al*, it is important to check if we can replicate Wit-

mer and Singer's results. We found that in both the low and high-collaboration VEs, the presence score and the IT score were positively correlated. This supports Witmer and Singer's results indicating that the immersive tendencies scores act as a predictor of the presence score.

When we compared the presence an co-presence scores, we found that there was no correlation between presence and co-presence in any of the two conditions. We therefore failed to replicate the results found by Tromp *et al* in one of their experiments [11].

3 Experiment 2: The Effects on Co-presence of Avatar Appearance and Functionality

In this section we present an experiment which is designed to investigate the effects that avatar appearance and functionality (in terms of gestures and facial expressions) have on co-presence in the collaborative virtual environment.

In this experiment we try to address the following issues:

- The effects that unrealistic avatars have on co-presence as opposed to human-like avatars. The important issue to determine here is how does the appearance of different avatars affect the sense of co-presence in the CVE.
- The effects that avatar functionality has on co-presence in the virtual environment. By functionality we mean avatars having simple gestures (waving, raising arms, joy and sad gestures, head movements such as yes, no and perhaps, walking) and facial expressions (sad, happy, neutral, surprised, disgusted, angry and furious).

In order to address the issues mentioned above, we divided the experiment into two parts. The first part (Part A) investigates the effects of avatar appearance on co-presence, and the second part (Part B) investigates the effects of avatar functionality on co-presence in the CVE.

3.1 Presence and Avatars: Hypotheses

In a Collaborative Virtual Environment avatars provide important information such as the existence of other participants, the location of other participants (position and viewpoint of others), the identity (who does the avatar represent), the activity that other participants are performing, and the availability of others (conveying some sense of how busy and/or interruptible a participant is) [1]. This information is crucial to establish and maintain the presence of other participants in the virtual environment.

This experiment involves the testing of two hypotheses.

The *first hypothesis* is that the way one represents other participants in the virtual environment is very important to enhancing the sense of co-presence. The important issue here is to determine how does the appearance of the avatar affects co-presence. In order to test this hypothesis, we provided the participants with avatars having different appearances. The avatars include realistic human-like avatars, cartoon-like avatars, and simple unrealistic avatars.

The *second hypothesis* states that simply having static avatars is not sufficient to create a high sense of co-presence in the collaborative virtual environment. We believe that providing simple gestures and facial expressions to the avatars will increase the sense of co-presence in the CVE. Here we will address questions such as: Are fully functional avatars, with gestures and facial expressions necessary or are crude representations of avatars sufficient to maintain the sense of presence of others ?

In order to investigate the hypotheses mentioned above we divided this experiment into two parts, which use the same virtual environment and have the same experimental scenario. Only the avatars provided to the participants differ between the two parts. In the first part (Part A), we investigate the effects of avatar appearance on co-presence. In the part (Part B), we investigate the second hypothesis which involves the effects of having gestures and facial expressions on the avatars.

3.2 Experimental Procedure

Part A used 18 participants, divided into 6 groups of 3 users each. Part B involves 30 participants divided into 10 groups of 3 users each. The participants were recruited from the second year psychology course at the University of Cape Town.

Before starting the actual experiment, each participant was introduced to the system. This involved learning how to control the avatar's gestures and facial expression if provided, move through the environment, pick up objects, etc. Once every participant was familiar with the interface, they read the experiment instructions stating the task that they will have to perform in the virtual environment.

The task consists of reading a story (4 short paragraphs) by accessing the book on the table in the VE. Once each participant has read the story, they have to agree on a ranking for the five characters in the story. The ranking is as follows: the best character is assigned a "1" and the worst a "5". There is a whiteboard on the VE which has a simple grid with the names of the five characters of the story. At the bottom of the board there are five numbers which can be moved around the board, so that the participants can assign the ranking to each character in the story. The

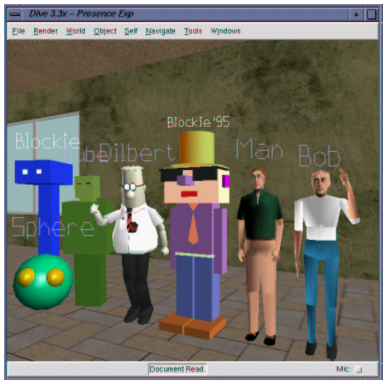

Figure 3: The avatars used in this experiment. From left to right, we have three unrealistic avatars, followed by two cartoon like avatars, and two human-like avatars.

participants have to argue with one another and arrive to a group agreement. This task requires communication to argue or agree with the other participant's rankings.

The avatars used by the participants were labeled Red, Green or Blue, and participants called each other by these names during the experiment.

The task had a time limit of 20 minutes, and after that each participant was required to fill in two questionnaires: Witmer and Singer's Immersive Tendencies Questionnaire, and the Presence/Co-presence Questionnaire. In this experiment we measured the following variables: personal presence (P), co-presence (CO-P), and immersive tendencies (IT).

3.3 Avatars Used

In Part A, in order to investigate the effects of avatar appearance, we provide a set of avatars divided into three categories: *realistic human-like avatars*, *cartoon-like avatars*, and simple *unrealistic avatars* (refer to Figure 3).

Figure 4: A realistic human-like avatar with simple gestures and facial expressions. The gestures provided are: waving, moving the arms, walking, head movements. The facial expressions available are: happy, sad, surprised, disgusted, angry and furious.

In Part B, in order to investigate the effects of avatar functionality, we provide some avatars with simple gestures and facial expressions (refer to Figure 4).

3.4 Results

3.4.1 Part A: Effects of Avatar Appearance on Co-Presence

We measured the following variables: the co-presence of realistic human-like avatars (CO-P-RHA), the co-presence of cartoon like avatars (CO-P-CA), and the co-presence of unrealistic avatars (CO-P-UA). We also measure the personal presence score (P), and the immersive tendencies scores (IT).

We compared the co-presence scores generated by the different avatars by performing a one-way ANOVA on the CO-P-RHA, CO-P-CA, and CO-P-UA scores. We found that there was a significant difference, having $F(2, 33) = 20.438, p < 0.001$. This difference indicates that the way one represents the avatars affects the feeling of co-presence felt by the participants.

A correlation analysis was performed on the P, CO-P, and IT variables to check if there were any significant relationship between them. We found a significant correlation $(p = 0.033)$ between the P score and the IT scores. We did not find a significant correlation between the CO-P scores and the IT scores, or between the P and CO-P scores.

3.4.2 Part B: Effects of Avatar Functionality on Co-Presence

We measured the following variables: the co-presence of static avatars (CO-P-S), and the co-presence of avatars with gestures and facial expressions (CO-P-F). We also measure the personal presence score (P), and the immersive tendencies scores (IT).

We compared the co-presence scores generated by static avatars (CO-P-S) and by avatars with gestures and facial expressions (CO-P-F), by performing a one-way ANOVA on the two variables. We found that there was a significant difference, having $F(1, 22) = 6.00678, p < 0.05$. This indicates that the avatars with gestures and facial expressions did create a significantly greater sense of co-presence.

We performed a correlation analysis on the P, IT, and CO-P scores to check if there was any significant relationship between these variables. We found a significant correlation $(p = 0.01)$ between the P score and the IT scores. We did not find a significant correlation between the CO-P scores and the IT scores, or between the P and CO-P scores.

3.5 Discussion of Results

The results show that there was a large and significant difference between the co-presence scores gen-

erated by the different types of avatars in Part A of this experiment. The co-presence generated by the realistic human-like avatars was greater than that generated by the cartoon-like avatars, which in turns was greater than the co-presence generated by unrealistic avatars. None of the avatars had any gestures or facial expressions. This indicates that realistic avatars having a human-like form engender a greater sense of co-presence that totally unrealistic simple avatars.

The results show that the co-presence generated by avatars having gestures and facial expressions was significantly higher than that generated by static avatars. This supports our hypothesis that states that providing simple gestures and facial expressions to the avatars will enhance the sense of co-presence in a collaborative virtual environment. It is important to note that the participants which had avatars with gestures and facial expressions had to use the GUI to control their gestures and expressions. This might have disrupted the sense of co-presence felt by those participants and so might have influenced our results.

We also found that the presence score (measured by Slater's presence questionnaire) and the IT score (measured by Witmer and Singer's immersive tendencies questionnaire) were correlated. This supports Witmer and Singer's result indicating that the immersive tendencies score act as a predictor of the presence score. When we compared the co-presence (CO-P) scores and the immersive tendencies (IT) scores, we found that there was no correlation between them. When we compared the presence (P) and co-presence (CO-P) scores, we found again that there was no correlation between them. We therefore failed to replicate the results found by Tromp *et al* [11] and Slater *et al* [8] in one of their small group experiments.

4 Conclusion

In this paper we present two small group experiments designed to investigate some of the factors which might affect personal presence and co-presence in a Collaborative Virtual Environment. The first experiment investigates the effects of group collaboration and interaction on presence and co-presence in a CVE. The second experiment investigates the effects of avatar appearance and functionality (in terms of simple gestures and facial expressions) on co-presence in the CVE.

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